3985 *

increased germicidal action of chlorine at low pH and effects excellent bacterial reductions with a low chlorine concentration by acidification, addition of chlorine, and after a very short contact time raising the pH to the desired level by addition of alkali. Equivalent kills are obtained with about 1/20 of the chlorine applied in about 6 ft of corrosion-resistant line at flows of 400 gal. per min.

Many tastes and odors in water can be removed by chlorination. Hydrogen sulfide in water is oxidized to sulfate at pH 6.4 or lower and also to free sulfur at higher pH values. Chlorine will remove some color from water and will oxidize iron and manganese for removal. Chlorine can react with phenols to form chlorophenols which have a very low taste threshold and, if formed, can be removed by activated carbon filtration.

H. GORDON HARDING

Cross-reference: *Flocculation; Ion Exchange.*

WHEY

Whey, the fluid portion of milk drained from the curd in cheese or casein manufacture may be sweet or acid. Of the 23 billion pounds of whey produced annually in the United States, about 25% is acid whey (pH 4.7) resulting from cottage cheese production. The remainder is sweet rennet whey (pH 6.2) from cheddar, Swiss and specialty cheeses. Casein whey, the U.S. production of which is small, contains the precipitating acid, either hydrochloric, sulfuric, or naturally-formed lactic. Billions of pounds of whey are produced in other countries notably in Europe, Australia, and New Zealand. In every whey producing area the problem of utilization vs. disposal into streams or sewers is being met by a vigorous search for new and profitable uses.

One hundred pounds of whole milk will produce about 10 lb of cheddar cheese and 90 lb of whey; 100 lb of skim milk will produce 16 lb of cottage cheese and 84 lb of whey or 2.8 lb of casein and 91 lb of whey.

Composition

Whey contains 1/2 the solids of the original milk; the fat and much of the protein are removed in cheese making. The composition of whey is shown in Table W-2. Whey is actually a 5% solution of lactose containing 2% of other milk components. It contains almost as much riboflavin as does milk. Acid whey contains more calcium and phosphate than sweet whey because of the solvent action of the acid used to precipitate the casein. The residual fat (0.3%) in sweet cheese whey is recovered by centrifugal separation. The protein is calculated from the nitrogen content of the whey or fractions separated from it. Whey, not treated to separate its proteins, contains β-lactoglobulin, α-lactalbumin, serum albumin, serum globulins, and other heat-denaturable proteins. Rennet treatment of the milk leaves a macropeptide in the whey which has a molecular weight of 8000; this macropeptide is split from κ-casein in the initial step of the clotting process. The proteins of whey may be separated by heat or heat plus acid and used in food preparation.

TABLE W-2

THE COMPOSITION OF WHEY

	Sweet Cheese Whey[1]	Cottage Cheese Whey	Casein Whey[1]
Lactose	4.9	4.6	5.1
Heat-coagulable protein	0.5	0.5	0.6
Nonheat-coagulable nitrogenous matter	0.4	0.4	0.4
Ash	0.6	0.7	0.7
Fat	0.3	0.1	0.1
Lactic acid	0.2	0.6	—
Total Solids	7.0	7.0	7.0
Water	93.0	93.0	93.0

[1] SOURCE: Nutting (1970).

The composition of a commercial, edible, dried, sweet whey is shown in Table W-3. This composition is typical of the products prepared for food manufacture. Products of similar composition, but usually containing more lactic acid and correspondingly less lactose, are dried for animal feed. At present more than 1/2 the dried whey produced in the United States is sold for animal feed at a price that barely covers production costs. A high protein whey feed is made by delactosing whey with a lactose fermenting yeast thereby replacing the lactose with yeast cells.

Nutritive Value

The nutritive value of whey is high in some respects but low in others. The fat and most of the protein have been diverted to cheese. However, the biological value of the remaining whey proteins is higher than that of casein but their concentration is low. Excessive heat during processing, especially during the roller drying of whey, may lower its amino acid values by rendering them, especially the lysine, biologically unavailable. Most of the lactose and minerals remain in sweet whey, less in acid (fermented) whey. A lactose intolerance exists in some people who lack ability to hydrolyze the sugar; this gives rise to temporary abdominal discomfort. Since 73% of whey solids is lactose, the amount of whey that can be consumed by

TABLE W-3

COMPOSITION OF COMMERCIAL DRIED SWEET CHEESE WHEY

Component	(%)
Chemical Composition[1]	
Protein	12.0
Fat	0.9
Ash	8.0
Lactose	71.0
Lactic acid	2.2
Calcium	0.6
Phosphorus	0.6
Sodium	0.7
Moisture	4.3
Amino Acid Composition	
Arginine	0.32
Methionine	0.25
Lysine	1.07
Tryptophan	0.22
Histidine	0.20
Isoleucine	0.74
Leucine	1.14
Phenylalanine	0.36
Valine	0.73
Threonine	0.83

[1] Values based on published figures from brochure *Whey Products from Kraft*, Kraft Foods, 1970.

lactose-intolerant persons is limited. Whey solids can make a positive nutritional contribution to foods when used at a 3-10% solids level.

TABLE W-4

VITAMIN CONTENT OF WHEY[1]

	Fluid	Dried
A (IU/100 gm)	11.0	50.0
	(Mg/Liter)	(Mg/Kg)
Thiamin	0.4	3.7
Riboflavin	1.2	23.4
Nicotinic acid	0.85	9.6
Pantothenic acid	3.4	47.3
Vitamin B_6	0.42	4.0
Biotin	0.14	0.37
Folic acid	—	0.89
Vitamin B_{12}	0.0020	0.021
Choline	—	1356.0
Vitamin C	13.0	—

[1] Many unidentified growth factors have been attributed to dried whey when used as an animal feed. See Hartman and Dryden (1965) from which the values in this Table were taken.

TABLE W-5

DRIED WHEY STANDARD FOR U.S. EXTRA GRADE

	Not More Than
Bacterial estimate	50,000/gm
Butterfat	1.25%
Moisture	5.0%
Scorched particle content	15 mg
Solubility Index	1.25%
Titratable acidity	0.16%

NOTE: Flavor, odor, and physical appearance must be normal as given in the standard.

The vitamin content of whey is given in Table W-4. When whey is concentrated and dried there is approximately an 11-fold increase in solids and this concentration increase is reflected by an increase in most of the vitamins as shown in Table W-4. Other properties of food grade dried whey are given in Table W-5.

Processing

Sweet whey must be processed within hours of its removal from the cheese curd to preserve its quality. Acid whey produced from casein or cottage cheese is more stable since lactic acid bacteria and many other organisms are inhibited in their growth at acidities below about pH 4.7.

The first step in processing is pasteurization which is usually followed by concentration and drying. Pasteurization is done at 180°-205°F. If denaturation of the whey protein is to be avoided temperatures below 165°F are used. The whey is concentrated under vacuum to 40-50% solids except in new reverse osmosis (RO) procedures. RO can be used to concentrate small quantities of whey (up to 100,000 lb per day) to 25% solids. This reduction in bulk facilities shipment to a central processing or drying plant where large scale vacuum evaporating and drying equipment is available. There should be at least 100,000 and 750,000 lb whey per day available, respectively, to justify installation of a vacuum evaporator or spray dryer. Large whey drying operations will handle from one to several million pounds of whey daily.

Most of the whey that is processed is dried to preserve it for shipment, storage, and handling as a food or feed ingredient. For this purpose a non-hygroscopic product is desirable. Since 70% of dried whey is lactose, which normally dries as a hygroscopic glass, the lactose is generally crystallized in the concentrate (50% TS) and during the drying process. Whey dried from this concentrate yields a stable, crystalline sugar which will not absorb moisture as will the syrup form. The powder is packaged in multiwall bags of 50-100 lb capacity.

Utilization of Whey

Sound factory and environmental practices demand that whey be salvaged for constructive purposes. Federal and state water quality standards have practically eliminated the practice of whey disposal into rivers and streams. Most municipalities are charging on a BOD basis for disposal into city sewers. Whey contains 6.3% organic solids. Its Biological Oxygen Demand (BOD) is the amount of dissolved oxygen taken up by the sample expressed in parts per million (ppm). The BOD measured over a 5-day period is expressed as BOD_5. The BOD_5 of 100 lb of cheddar cheese whey is 3.5 and the population equivalent is 21. Thus, 5 lb of whey is considered to cause pollution equal to that of the waste from an average individual. A cheese plant discarding 100,000 lb of whey per day would then require sewage disposal facilities the size of a town of 20,000 people. The importance of processing whey into useful feed or food products is clearly indicated.

Whey has long been fed to swine and other farm animals but part of the supply is now bringing better prices as a food ingredient. Lactic acid, alcohol, and vinegar were whey products for many years. Recently, however, whey has been largely displaced by less expensive fermentable materials. Whey is the raw material for lactose production and the amount of lactose manufactured is limited only by the uses that can be found for this unique carbohydrate. Small quantities of whey solids can be used in cheese spreads and in process cheese, and have been gradually displacing part of the nonfat milk used in bakery goods, confections, and ice cream. It is especially adaptable to sweet baked goods because it produces a soft cake-like texture. In ice cream, the addition of whey is permitted in an amount not to exceed 25% replacement of the nonfat milk solids. When it is used to increase rather than replace milk solids, an improvement in body and flavor results. Ten to 15% of fudge or caramel solids can consist of whey solids to the improvement of both body and flavor of these candies. Nutritionally, whey could be an important ingredient in fruit-flavored beverages and soft drinks but this market is still undeveloped.

Whey protein and lactose fractions are prepared for food manufacture by several fractionation or concentration processes. A high degree of purity often is not necessary when the whey product is to be used directly in food. Electrodialysis will take out part of the salts from which some of the lactose may have been already removed. Fractionation by ultra filtration (UF membranes, a form of reverse osmosis), is a newly developed procedure which has been made possible through the availability of improved long-lasting membranes. Typically, a fractionation membrane can remove 90% of the cottage cheese whey volume as permeate containing 80% of the lactose and more than 90% of the ash. The remaining high protein fraction resembles skim milk in its proportions of lactose, protein, and salts. Thus, on a dry weight basis, if the original cottage cheese whey contained 68% lactose and 8% protein, a dry protein concentrate could be produced containing 33% protein and 52% lactose.

Gel permeation can be used to obtain high protein fractions by flowing the whey over a column packed with a suitable gel (Sephadex) which retains the smaller molecules of salts and lactose. The separation can be made more effective by first making an ultra filtration membrane separation. Such a concentrate may contain up to 80% of its solids as protein. Protein concentrations of 60-75% of solids can also be produced by diluting the first UF concentrate with water and refiltering it.

The economic aspects of whey utilization largely govern its final disposition. Whey has many possible uses but the cost of preparing it for special purposes must not cause it to lose its competitive position with alternate materials. It costs almost as much to dry and bag as it will bring as a feed ingredient (about 4¢ per lb). In unprocessed liquid form it can be fed to swine or recycled back to the cows, but again handling costs are scarcely recovered as available nutrients for the animal. Nevertheless, processing as feed at a break-even price is better than paying a BOD charge for waste disposal. Whey solids are most valuable as human food, especially when high protein preparations are made from it. These too must be competitive with casein, vegetable protein, and egg white.

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Cross-references: *Market Milk Industry; Ultrafiltration and Reverse Osmosis.*

WINE

Fermented beverages have been produced since the Paleolithic period—probably at first by accident from honey. Later, cereals were used, and then grapes and various fruits. Soma and other early beverages were probably produced from honey or honey-cereal-fruit mixtures. During the Neolithic period beer from fermented cereals was most popular in the Middle East and Egypt. Wines from fruits, and especially from grapes, were more popular in Greek and Roman territory.

Artifacts of the manufacture of wines begin to appear about 3000–4000 B.C. in the Middle East. The culture of the vine, which made this possible, spread from the Middle East to the Mediterranean where it achieved and still maintains its largest culture. The date and fig were also fermented during the neolithic period. Other fruits, such as the peach, pear, apricot, and berries, were fermented as they were domesticated, but never in quantities approaching grapes. Since the sugar content of fruits is low (except for the date and fig) they produced a low-alcohol, easily-spoilable beverage. They were, therefore, not popular. Except as a minor household industry and in cold regions where grapes do not grow, wines from fruits were and remain of relatively minor importance. Apple cider and perry (from pears) are local exceptions. More popular are liqueurs distilled from these fruit wines: Kirschwasser (from cherries), slivovitz (from plums), framboise (from raspberries), etc.

Earthenware jars (called amphora by the Greeks and Romans) were used to store and transport the wine during and after the Neolithic period. During the period of Greek expansion throughout the Mediterranean, a lively trade in wines between Greece and her far-flung colonies and other nations developed. Later, vines were planted by the colonists and wines were produced in the colonies. Gradually, the vine was introduced to all the countries around the Mediterranean and Black Sea basins, and from them to adjacent regions (Germany, Hungary, Rumania, etc.). Still later, culture of the vine spread throughout the temperate zone as the following 1972 acreage and production figures show, reported by the Office International de la Vigne et du Vin Bull. *46* (1973):

	Acreage (1000 A)	Production (1000 Gal.)
Europe	15,793	5,915,770
Asia	2,601	52,980
South America	1,212	710,490
Africa	1,133	349,945
North America	546	267,551
Oceania	144	72,484
Total	21,429	7,369,220

Obviously the greatest acreage and most of the wine production is in Europe. Italy, France, and Spain are the largest producers.

Influence of the Raw Material

Varieties of the European grape, *Vitis vinifera*, proved to be an almost ideal media for alcoholic fermentation. As wild types normally ripen they contain 10–20% sugar and have 1–2.5% acidity (as tartaric). As varieties were domesticated those of higher sugar and lower acidity were selected. Under favorable climatic conditions grapes of *V. vinifera* easily reach 18–24% sugar with only 0.5–1.5% acidity.

In the Western Hemisphere, and specifically in Eastern United States, other species of *Vitis* grow wild. During the first half of the 19th Century a number of these were domesticated—primarily varieties of *Vitis labrusca*. Some of the seedlings that were propagated were probably chance *V. labrusca* x *V. vinifera* hybrids. The domesticated native varieties and the hybrids withstood the cold winters of this region and were more resistant to fungus, virus, and insect diseases than *V. vinifera* varieties. About 10–15% of U.S. wine production is from these varieties: Catawba, Concord, Delaware, Ives Seedling, Niagara, French hybrids, etc.

Production.—Even before the Greek period viticulturists had learned to curtail overproduction by pruning. Wine grapes of 18–22% sugar and no more than 0.6–1.5% acidity (as tartaric) could be produced not only in the Mediterranean region but also in cooler areas.